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Catching Up With BIM: A Curriculum Re-Design Strategy

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ABSTRACT

BIM has been discussed widely for enabling collaboration in AEC professions. Its widespread benefits from efficiency to sustainability in design and construction converted it into a primary tool in most AEC education institutions in the last decade. However, Turkey, like a part of the central Europe, remains hesitant in this concern. The majority of schools of architecture have conventional curricula based on fragmented areas of expertise studied separately with disconnected contents, teaching methods, and requirements. This separation not only prevents the students from building links between different contents of sustainable design, but also increases their work load while decreasing their creative potential. Regarding the necessity for collaboration in the growing complexity of built environments, underdeveloped skills in building links between fragmented data bases is eventually becoming a serious problem. After scrutinizing the fragmented curricula of the schools of architecture in Turkey, in comparison with the integral examples from around the globe, the potentiality of a BIM based transformation is going to be discussed. In order to build a strategy to redesign a curriculum of integration, apparent obstacles and potentials are going to be evaluated, with example cases for the use of BIM as a medium to include environmental and structural information in the design solutions from the second and third year students of architecture at Başkent University. This study is expected to demonstrate how provoking the skill to employ BIM can be to integrate creative educational experience in architecture, at the center of which remains the design studio. The discussion concludes by suggesting pathways to catch up with the growing gap between the global evolutions of interdisciplinary and integral design thinking through the use of BIM in AEC education.

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1. Introduction

There is a consensus that BIM and its adoption provided a shift in AEC professions (Azhar et al., 2015), which would yield to the transformation of the higher education of AEC disciplines

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(Briscoe, 2016; Scheer2014; Barison and Santos, 2010; Deutsch, 2017). According to Scheer (2014) the transformation by BIM would lead to a redefinition of an architects' role in the creation of buildings. This redefinition requires the academia to reevaluate the profession and its education continuously. The requirement for the interconnection between the academia and the profession is even stronger today.

Because there is not enough research on the industrial requirements or on the educational opportunities or limitations in Turkey, the need for a study on adapting the architectural curricula to BIM based integration has two motives. The first motive is educational, which is on the opportunity provided for achieving an integrated learning environment, in line with the constructivist educational theory (Jonassen, 1999). And the second motive is industrial, where the construction sector deals with large scale and complex projects and constitutes a leading role in the national economy. The big number of ongoing and future large scale projects of high complexity also require minimized errors in design and construction projects to be delivered in very limited times, without taking project based economic risks.

Although it is known that the requirement for BIM experience is increasing, the number of research studies on the spread of BIM among professionals in Turkey is quite small. However, there is a growing need for a BIM based architectural education, which is the consequence of the professional requirement for highly complex building and construction process designs and control. One feature of this overall transformation is the multi-disciplinary working environment, where each profession can work on the same BIM model, separately but interdependently. Therefore, the problem of adapting architectural education to prepare graduates ready for a BIM based professional practice is not only about learning to use the BIM software limited with a single disciplines conventional practices.

There are two major research questions that this study deals with:

- How can the existing condition of architectural education in Turkey be transformed to prepare for a BIM based practice of building design and construction regarding the existing possibilities and limitations?
- Is it enough to deal with the problem from the potentials and limitations of the existing conditions or is it a paradigm shift that is required in the overall understanding of architectural education?

The discussion is based on the potential of BIM as a medium for resynthesizing architectural knowledge as a comprehensive whole for an integrated learning environment in the educational settings.

2. Recent approaches to BIM in higher education of AEC disciplines

As Azhar et al. (2015) put it, the practical implementation of the BIM tools started in the mid-2000s the technology of which is based on the technique of object-oriented parametric modelling. The authors explain what parametric is, with its feature that when a change is made in an object results in necessary changes in other objects, with which it has previously defined relationships. (Azhar et al., 2015). It is this feature of BIM that made it a central concern in AEC professions, which resulted in increasing number of schools that started to implement BIM into their curricula. In order to understand the current trends in this implementation, many researchers continue conducting surveys regarding the educational realm (Barison and Santos, 2010; 2012; Adbirad and Dossick, 2016; Becerik-Gerber et al., 2011; Joannides et al., 2012).

As Adbirad and Dossick (2016) state, the transition of education under the BIM influence occurred mostly as the transition of CAD teaching courses to BIM teaching courses until 2010. According to the authors, after 2010, the process of integrating BIM into core courses begun, shaping the curricula with regards to the industry participants' and academics' views on BIM. As the author state, most recently two major themes have emerged. One of them is related with the cross disciplinary collaboration and the realization of these practices in the educational curricula. The other one is based on the in-depth analysis of innovative pedagogical strategies (Adbirad and Dossick, 2016).

Based on the general conception that sees BIM as an instrument of a paradigm shift in architectural practice and education, Barison and Santos (2010) focus on how the universities around the world deal with the introduction and/or integration of BIM into their curricula. As the authors put it, by 2010 the integration of BIM into AEC curricula had reached a range of eight categories, as depicted by the authors, some of which occur together in some programs: "Digital Graphic Representation (DGR); Workshop, Design Studio; BIM Course; Building Technology; Construction Management; Thesis Project and Internship."

Becerik-Gerber et al. (2011) have also made a survey across the US schools of higher education

of AEC disciplines in 2009, which depicted that an overall 56% of all programs in their survey had offered BIM courses, which had started earlier in the schools of architecture. It was in that survey that the authors depicted that almost all of the programs which had not yet included BIM in their curricula were planning to incorporate BIM into them within a year or two.

It is interesting that Becerik-Gerber et al.'s (2011) study depicts that in 2009, in many architecture programs, BIM was assumed to hinder creativity. The article does not give a specific reason for this belief but what the authors state by quoting from Denzer and Hedges (2008) is important, which indicates that the biggest challenge for design instructors is the new teaching methods required with BIM. This might mean that it is not BIM that hinders creativity, but the current educational methods require a transformation to fulfil a creative insight to be achieved via BIM. These methods are mostly about employing BIM as a teaching tool to demonstrate the course content (eg. construction detailing) on the BIM model. According to Morton (2012), BIM has a creative potential starting from the early conceptual design and academia has to fulfil it.

3. The predominating role of collaborative design in BIM implementation

With the feature of object oriented parametric modelling (Azhar et al., 2015), BIM supports the concept of Integrated Project Delivery (IPD), which means collaborative building design and construction practices. As he states, it requires the multiuser access to the BIM model to integrate multidisciplinary information in the same model (Azhar et al., 2015, 24). This is interoperability of a BIM software referring to its ability to provide working media and feedback to all of the stakeholders of the project through a single BIM model. This feature brings the opportunity of collaborative design, in which the design task is divided into parallel sub tasks that can be progressed simultaneously. Division of labor is the sharing of problems into the sub problems of different professional databases. That the task is not completely separated which is the essence of collaborative work, instantaneous feedback and test outcomes can be utilized for faster and flawless problem solutions. As Kozar (2010) explains the direct interaction of collaborators is different than cooperation where different parts of a problem are solved separately and then brought together. In line with this state Azhar et al.:

"BIM represents a new paradigm within AEC, one that encourages integration of the roles of all stakeholders on a project. This integration has brought greater efficiency and harmony among players who all too often in the past saw themselves as adversaries." (Azhar et al., 2015, P.25)

According to Kymmell (2008), The relation between the complexity of a real life architectural design problem and BIM based design process should be included within the educational curricula. He regards collaboration as the fundamental principle to the whole BIM process and asserts that "learning collaboratively is excellent preparation for the psychological mind set necessary to work with the BIM process." As he underlines it, team building and processing is not a natural skill, it has to be developed (Kymmell, 2008). If the students do not acquire the experience of team working in collaborative design project solutions during their educations, they will not actually fulfill the required BIM skills even if they have learned how to use a BIM software in an advanced level.

Deutsch (2011) also underlines the importance of knowing how to collaborate and integrate the design working process. He cites from Charles Hardy, the director of GSA Office of Projects Delivery, about his statement asserting that only 10% of BIM is technology, while the remaining 90% is "sociology". He uses the terms "mindset" and "attitudes" for expressing the state of readiness for BIM implementation as the ultimate necessity (Deutsch, 2011). As Becerik-Gerber et al. (2011) assert, the problem of collaboration and IPD is not only the problem of the schools of architecture. As a result of the literature review that they have conducted they state that today's engineering graduates are also required to have developed team-working and multidisciplinary collaboration skills. Moreover, the authors have depicted that the rate of multidisciplinary collaboration was lower than expected (Becerik-Gerber et al., 2011).

4. The relation of educational transformations with the industrial requirements.

Azhar et al. (2015) assert that BIM is a revolutionary tool for AEC industry. Likewise, Briscoe (2016) regards BIM as a source of inspiration that is potential to change how architecture is perceived and practiced. According to him, it was when CAD dominated representation in architecture that information became fragmented (Briscoe, 2016). According to Scheer (2014), the separation of design and construction that dates back to Alberti in Renaissance, has come to an end with the replacement of drawing by simulation provided via BIM. What he means by this merging of design and construction is involving the construction and technical data at the early

stages of conceptual architectural design. This might even include, as Leon et al. (2015) exemplify, the inclusion of other disciplines as consultants or design team members at the conceptual design phase. This depiction of merge after a long break since renaissance is worth attention as it also means that in architectural education this integration is also inescapable and is going to become fundamental.

Collaboration is an ultimate part of IPD and the concept of integration requires as much attention. Briscoe (2016) points to a different facet of collaboration, which is not real collaboration but requires attention for the integrative role that it takes. As he states, the case of downloading BIM objects from the manufacturers' object designs, which is now possible with the shared BIM content, makes it possible to host another designers' highly detailed and informed system design in the definitive BIM environment. As he puts it: "This exchange suggests a culture of collaboration, so to speak, in borrowing information from the workflows, opinions, and values of others (Briscoe, 2016)."

According to Scheer (2014), simulation is replacing representation, by which he means the tools for thinking for design solutions have been exposed to a shift by the adoption of BIM and computational design in the AEC industry. When taken from the educational perspective, it is important to understand that adopting BIM especially for constructional and structural information based courses at least partially for the beginning is essential.

As Deutsch (2017) asserts, it is not only the tools but also the current state of the design community that leads the convergence in building design, fabrication, and construction. By convergence he means two or more things evolving together into one. He expands this concept of integration with its three features: simultaneity of the real time decisions, superintegration of collaboration practices, and convergence of attitudes – approaches in building design and construction. He expresses the shift in architecture with this new converging nature of the profession (Deutsch, 2017). Convergence as he discusses it, implies the change in the way that architecture is practiced and how architects are educated. In line with Kocatürk and Kiviniemi (2013) Deutsch also argue that this is a process of transformation which requires the reappraisal of architecture.

There seems to be a one way relation in between the industry and academia, which results in AEC education responding the expertise requirements of the industry. Looking form this perspective, academia in general remains short in catching up with the required developments in industry. The reason for this is that academia is assumed passive in generating knowledge on the problem of integration in building and design construction processes. Regarding this misconception, Becerik-Gerber et al. (2011) argue that AEC education must take the leading role in the shaping of industrial requirements rather than trying to answer the arising industrial requirements.

5. The current condition in Turkey: integration of BIM in the curricula

It has been almost a decade now since Becerik-Gerber et al. (2011) completed their survey across US, the results of which were given above, and in contrast with it still there is not a significant rise in the number of studies on the reflections of BIM integration in the higher education of AEC disciplines in Turkey. Türkyılmaz's (2016) article is an example for BIM integration in architectural education, which explains the objective of the BIM course of a university in İstanbul, Turkey as the consistent production of the complete set of building representations and documentation. The author expresses the capabilities brought by BIM without including the multidisciplinary collaboration feature. Nor does he explain the practical and cognitive outcomes of the integrating function of BIM.

However, this single example should not mean that there is a dominating ignorance for the integrating role of BIM in Turkey. Indeed, Türkyılmaz's discussion is limited with the individual design practice of a single discipline, because of the current state of the educational curricula. Being aware of the potentials and requirements of BIM integration, Meterelliyoz & Özener (2017) argue that the use of BIM in education should not be limited with drawing, production and visualization and that the predominating potential of BIM on integrated design should be considered as a pedagogical input that can transform education. Based on this motive, the authors have analyzed the existing curriculum of a school for its early stages of architectural education to understand the adaptability of BIM based pedagogy, and it included understanding the convention of the courses on building systems and construction detailing. This is an example of what to do when BIM integration is late in architecture education.

6. The reasons for delay in integrating the curricula

To explain the problems of architectural education, Barison and Santos (2010) cite Fien and Winfree (2012) for their depiction that higher education of the AEC profession has been slow in adapting to technological expectations of the industry. As expressed earlier, one reason could be the attitude of academia on misleading its role and merely trying to catch up with the requirements of industry. This indicates a lack of academics that understand the inevitable transformation caused by the new paradigm of IPD and the collaborative nature of building design caused by it. Regarding this, Mandhar and Mandhar (2013) criticize the way schools of architecture uptake BIM technology for the general misunderstanding of its overall application. They put forward two possible reasons for this problem: the first is the lack of competent staff to teach BIM thinking and the second is the indecisiveness between teaching a software or the technology and process behind it. As the authors state, the implementation of BIM "…can only be achieved with a coordinated effort between teachers, the school, senior management and the university, as pedagogical changes for integrating BIM will need departmental or even inter-departmental restructuring to ensure that it is well integrated within the curriculum and is taught effectively by staff who have specialist knowledge and a background in the subject area (Mandhar and Mandhar, 2013)."

As an example of a slow transformation towards the BIM methodology, Boeykens, et al. (2013) express the case of Belgium as not being able to convert the methodology from mono-disciplinarity to cross-disciplinarity. They argue with refrence to and in line with Lockley (from the NBS Building Information Report (Anon, 2011, p.20+21), that the educational institutions have a big role in the transformation towards a BIM based education, which would include learning the mind for cross disciplinary collaboration.

In their systematic literature review, Adbirad and Dossick (2016) indicate that the research articles by the authors who focus on the future of BIM based education in AEC courses were advocating that solely mastering BIM software in a BIM course "is not effective for long-term BIM implementation." But the BIM software skills are desired by the industry professionals as developed in the university education. The authors argue that BIM instructors should cover both (Adbirad and Dossick, 2016).

As Barison and Santos (2010) cite from Taylor et al. (2007), BIM has the potential to take place throughout the program, which would mean at every level and for many differentiated content. This is where the integrating role of BIM is coming from. However, the research that Becerik-Gerber et al. (2011) conducted in 2009 revealed that BIM was mostly used in design visualization and constructability activities. The most common reason for not having integrated BIM in the curriculum is the lack of the required teaching staff. Kymmell (2008), puts forward another requirement for BIM integration. In his "recipe for successful learning" of BIM, he gives the example of BIM curriculum at California State University, Chico as a developed one. Based on the evidence he gives from that example, he asserts that success in learning to use the potentials of BIM requires motivation and full-heartedness (Kymmell, 2008). This may include the projected learning outcomes be reevaluated for a meaningful integration based on shared objectives where the courses meet at a comprehensive meaning within the students' overall educational experiences. The expected learning outcomes of integrated education would include self-competency resulting from knowing where to find what is looked for and knowing what is missing, knowing how to consult and using a simulation medium to test the proposals.

Another reason behind being late in transition is little or no teamwork or collaboration. However, the opportunities brought by BIM would also have merits for improving architecture students' creative skills. In a previous study, the positive feedback of structuring the design process of ill-defined problems was discussed (Açıkgöz, 2015). The idea that team working needs a structured process for interactive and uninterrupted communication among the team members to fulfill the opportunities provided with teamwork was supported with the findings of a case study. The findings of that study could also be supportive for asserting that the nature of architectural knowledge is demanding collaborative work for the development of competency through creative act.

7. The risks of fragmented curricula:

Learning in architecture is a personal task (Acikgoz, 2010). It includes students' personal educational experiences, developing their personal libraries; content libraries, portfolios, lecture notes and the like. A student has a set of information and products that belongs to his educational experiences most of which reflect the content of his/her learning. When this is the case, the fragmentation of educational experience provides the students with exhausting and time consuming challenges to

start the technical research for each project from scratch and complete the process mostly without fulfilling the minimum requirements for technical issues.

Türkyılmaz (2016) states that BIM is only used for the design studio practices in architectural education. In line with that, in the course that he explains, the IFC format has a specific place in the curriculum (Türkyılmaz, 2016), but its merits for BIM based multidisciplinary collaboration during the design and construction processes is missing. This indicates the extents to which fragmented curriculum may lead the opportunities provided by the BIM tools towards a misdirection. Deutsch (2011) seems to ask the right question regarding the current curricula about BIM and integrated design: "What, in the learning process, needs to be unlearned?" According to the author, the problem of implementing BIM in education is not about learning software, but about becoming familiar with the collaborative process and the concept of integrated design (Deutsch, 2011).

In order to understand the span of the problem caused by the fragmentation of the content of architectural design, it is necessary to understand the content of student experiences in their educational settings. A comprehensive content analysis was not made for this study, but to draw general perspective, personal experiences as an educator, and a former student of architecture in Turkey, who has experiences of study and work in three different schools of architecture, can be used to pose the question about the problem of disintegrated education. For example, the following picture of student experience is worth of attention.

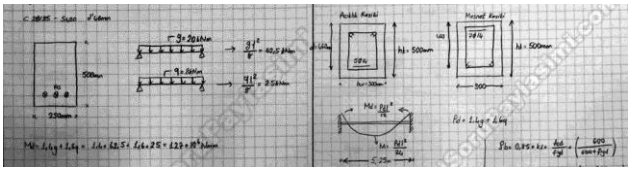

Figure 1. Portions of typical answer sheets of the reinforced concrete elements' section calculations and moment diagram (Source: sorupaylasimi.com)

The third year students of architecture in their course on "structural design in architecture", make the sectional calculations required to understand the dimensions and steel reinforcement, due to the forces acting on a single reinforced concrete element in a written exam (Figure 1). In the same week, they take critics for the solution of a concept design that does not have a structural support system yet for their design studio course. This is the educational realm experienced as a student, and observed as an instructor of 15 years which has not altered a little in this period, and which is the literal outcome of the problem of disintegrated curriculum. A similar picture can be drawn for the courses on energy efficiency, architectural history, material and construction systems, and even for city planning courses. This is a problem of not acquiring the experience of integrating knowledge, which not only endangers fulfilling the changing requirements of AEC professions. Regarding Kocatürk and Kiviniemi's (2013) argument on how architecture should contribute to the development of BIM thinking, it is possible to think that it also threatens the disciplinary existence of architecture as a profession.

7. Displaying potential for integration through samples of student works

The research method of the study is based on sampling the 3rd and 5th semester student works for displaying their potential for an integrated curriculum design. The 2017-2018 Fall semester was the first semester that the students of the Department of Architecture at Başkent University were introduced with a BIM course in the curriculum which was converted from a former CAD course. It is important to state that none of the students from the 2nd or 3rd year had a previous experience in any BIM software before taking the courses. Fortunately, there were different courses for these two different grades that focused on CAD based representation and modelling. Therefore this semester could be the semester of implementing BIM into the curriculum of the department from scratch.

Figure 2 displays three examples of the works of the fifth semester students, who were 75 in total number. The works are the outputs of the final examination of the BIM course that lasted for 90 minutes in total, in which the students were asked to design a mass model of a high-rise building with a base, convert it to a BIM project and submit in an A0 size designed sheet in pdf format including renders, elevations and plans. 90 minutes is a very short time to prepare and submit a conceptual output when compared with the traditional design and representation media or CAD. The outcomes were mostly valuable because they displayed the speed of working with BIM, which is going to become a fundamental requirement especially in multidisciplinary collaboration.

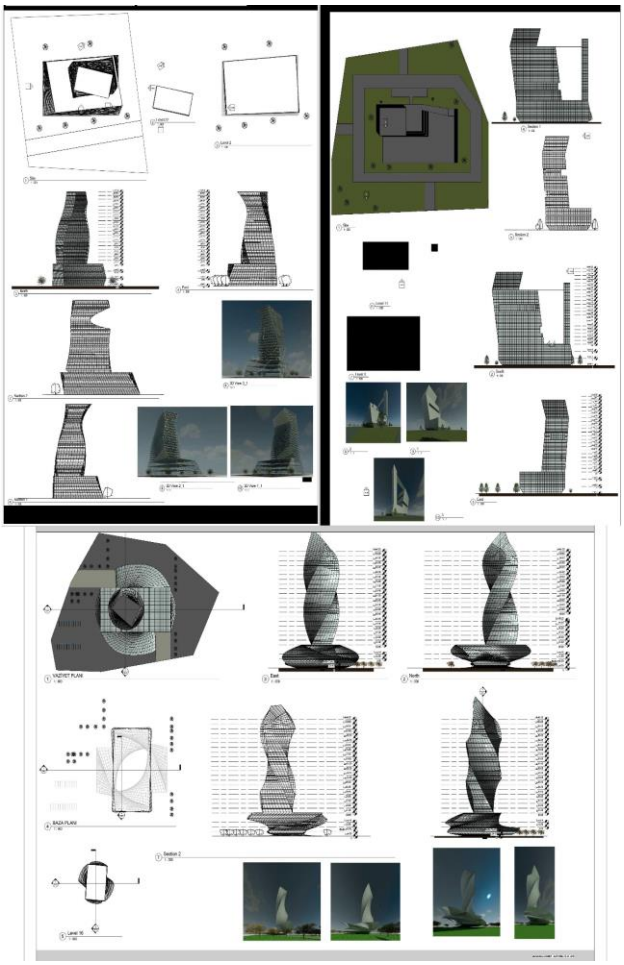

Figure 2: Three of the total 75 5th semester students' final exams' presentations

Figure 3: Sample BIM model renders given to express the solar conditions of the 3rd semester students' final design studio projects.

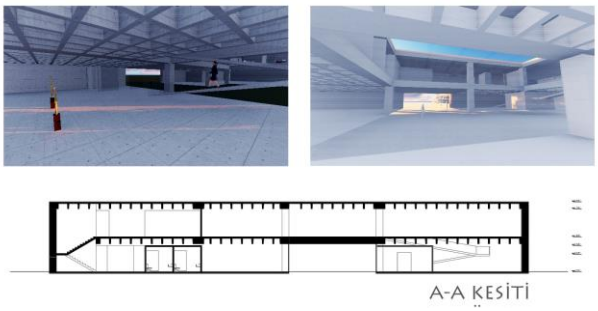

Figure 4: Sample BIM integration in the design studio of 3rd semester students.

In their 3rd semester, the students of architecture take a must course on basic construction principles and solution methods of structural systems including reinforced concrete. In figure 4 a student has integrated her structural design knowledge into her design studio experience through the use of BIM.

The given examples from Başkent University Department of Architecture display the consequences of implementing a BIM course into curriculum. It is evident that the students are enthusiastic about integrating their knowledge base in the design studio, which has been regarded as the core of architectural education for a long time. It is important to note that there was not a specific requirement for this integration by the instructors of the department. The question is what would happen after a fully integrated curriculum in architecture after managing to solve the limitations mentioned above could be overcome.

8. Conclusion:

Being late in adopting the required transformations in AEC education has many disadvantages in terms of catching up with the developed and progressed merits of integrated building design and construction in education and in practice. However, it also has an advantage, which is being able to reach the researches on schools of architecture that have overcome the obstacles of teaching BIM.

One of the most important findings that should be kept in mind is the depiction that academia should take the leading role in determining the development of BIM based integration from industry (Becerik-Gerber et al., 2011). This requires in Adbirad and Dossick's (2016) words, the in-depth analysis of innovative pedagogical strategies to get prepared for coming to the grounds of studying the cross disciplinary collaboration and the realization of its practices in the educational curricula.

Being a BIM instructor of five years' experience, it is possible for the author to argue that the long-term BIM implementation cannot be possible without being competent with a BIM software at least at the intermediate level, however, the objective to acquire the software skill may have limitations of its own, like feeling limited with the previously reached solutions of the software. Therefore, there should be a practice based instruction on the BIM software, but understanding the BIM thinking is necessary if the students are expected to use BIM as a design tool for creative processes in their own design work. This means that they have to be explorative for differing potentials, opportunities and limitations of the tools that they are using in order not to be controlled by what the tools can do.

However, in order to answer the need for collaborative design experience in monodisciplinary and interdisciplinary educational settings, the curricula should be examined for the existing material to adopt accordingly. For example, As Azhar et al. (2015) put it, BIM provides sustainable design analysis at the pre stages of the design, which is as they put it, the most critical phase for decisions on sustainability features (Azhar et al., 2015, 22).

This is important regarding Becerik-Gerber et al.'s (2011) study which examines the sustainability based courses with their integrating feature, having a relevant solution base to be converted to BIM based courses. The sustainability and sustainable construction courses also have an interdisciplinary span of content.

A BIM based curriculum requires a structured process of collaborative design study. But where this collaboration starts and how the team working experience can be a part of an integrative curriculum are the questions that need to be answered. It is however apparent that BIM can be used as a tool for architectural curriculum to transform from the system of fragmented content to an integrated education. The integration requires experience; students' experiences must be the base to integrate different content. But is this experience only building a BIM model, or building it collectively in the design studio? Kymmell's (2008) recipe for successful learning would not work if the students are more motivated in the design studio than in the courses of other fragmented content.

According to Deutsch (2017) the result of convergence in AEC professions must be more than only increased efficiency, it also leads us to a future where the boundaries between AEC professions are mostly blurred or disappeared. Therefore, assuming the completion of the catch-up with BIM implementation in education and even the state of leading the AEC professions, it would be reasonable to get prepared for redefining the AEC disciplines including architecture and questioning their fragmentation too.

References

Abdirad, H., & Dossick, C. S. (2016). BIM curriculum design in architecture, engineering, and construction education: a systematic review. *Journal of Information Technology in Construction (ITcon)*, *21*(17), 250-271. http://www.itcon.org/2016/17

Açıkgöz, E. K. (2015). "Uncovering Creativity: Structuring experience in architectural design studio", *Open House International* (SSCI & AHI), Vol.40 No.2, 2015. http://www.openhouse-int.com/abdisplay.php?xvolno=40_2_2

Açıkgöz, E.K. (2012). Continuity of personal knowledge construction through creative act: First year architecture education reconsidered as a medium for transition. *LAP LAMBERT Academic Publishing*. https://www.morebooks.shop/store/gb/book/continuity-of-personal-knowledge-construction-through-creative-act/isbn/978-3-659-25309-6

Azhar, S, Khalfan, M & Maqsood, T (2012), 'Building Information Modelling (BIM), now and beyond', *Australasian Journal of Construction Economics and Building, vol. 12, no. 4, pp. 15-28.* http://epress.lib.uts.edu.au/journals/index.php/AJCEB/article/view/3032/3245

Barison, M. B., & Santos, E. T. (2010, June). BIM teaching strategies: an overview of the current approaches. In *Proc., ICCCBE 2010 international conference on computing in civil and building engineering*. http://www.engineering.nottingham.ac.uk/icccbe/proceedings/pdf/pf289.pdf

Barison, M. B., & Santos, E. T. (2012). A Theoretical Model for the Introduction of BIM into the Curriculum. In *Proceedings of 7th International Conference on Innovation in Architecture, Engineering and Construction (AEC 2012), 15-17th August*. http://www.uel.br/pessoal/barison/Artigos_Tese/AEC2012.pdf

Becerik-Gerber, B., Gerber, D. J., & Ku, K. (2011). The pace of technological innovation in architecture, engineering, and construction education: integrating recent trends into the curricula. *Journal of Information Technology in Construction (ITcon)*, *16*(24), 411-432. https://www.itcon.org/papers/2011_24.content.09244.pdf

Boeykens, S., De Somer, P., Klein, R., & Saey, R. (2013, September). Experiencing BIM Collaboration in Education. In Computation and Performance-eCAADe 31 (pp. 505-514). Delft University of Technology. http://papers.cumincad.org/data/works/att/ecaade2013_103.content.pdf

Briscoe, D (2016) *Beyond BIM: Architecture Information Modelling*, Routledge: London and New York. https://www.routledge.com/Beyond-BIM-Architecture-Information-Modeling/Briscoe/p/book/9781138782495

Deutsch, R. (2011). *BIM and integrated design: strategies for architectural practice*. John Wiley & Sons. https://meyar.co/wp-content/uploads/2017/02/BIM-and-Integrated-Design-Strategies-for-Architectural-Practice-1.pdf

Deutsch, R. (2017). *Convergence: The Redesign of Design.* John Wiley & Sons. https://www.wiley.com/en-us/search?pq=Convergence%3A%20The%20Redesign%20of%20Design%7Crelevance

Jonassen, D. H. (1999). Designing constructivist learning environments. *Instructional design theories and models: A new paradigm of instructional theory,* 2, 215-239. http://www.davidlewisphd.com/courses/EDD8121/readings/1999-Jonassen.pdf

Kocaturk, T., & Kiviniemi, A. (2013). Challenges of integrating BIM in architectural education. In *eCAADe 2013: Computation and Performance–Proceedings of the 31st International Conference on Education and research in Computer Aided Architectural Design in Europe*. https://repository.tudelft.nl/islandora/object/uuid%3Ac5dcdf00-b2f6-4052-807e-b4a3a0e81e10?collection=research

Kozar, O. (2010). Towards Better Group Work: Seeing the Difference between Cooperation and Collaboration. In *English Teaching Forum* (Vol. 48, No. 2, pp. 16-23). https://americanenglish.state.gov/files/ae/resource_files/forum_article_towards_better_group_work-_seeing_the_difference_between_cooperation_and_collaboration.pdf

Kymmell, W. (2008) "Building Information Modeling: Planning and Managing Construction Projects with 4D CAD and Simulations." *McGraw Hill, New York, NY*. https://www.mhprofessional.com/9780071494533-usa-building-information-modeling-planning-and-managing-construction-projects-with-4d-cad-and-simulations-mcgraw-hill-construction-series-group

Leon, M., Laing, R., Malins, J., & Salman, H. (2015). Making collaboration work: Application of a Conceptual Design Stages Protocol for pre-BIM stages. BIM in Design, Construction and Operations. *WIT Press, Wessex, UK, 205-216*. https://openair.rgu.ac.uk/bitstream/handle/10059/1316/Leon%20BIMDCO%202015%20Making.pdf?sequence=1&isAllowed=y

Mandhar, M., & Mandhar, M. (2013). BIMing the architectural curricula: integrating Building Information Modelling (BIM) in architectural education. *International Journal of Architecture*, *Volume 1, Issue 1, pp1-20*. http://eprints.lincoln.ac.uk/8839/7/BIMING%20THE%20ARCHITECTURAL%20CURRICULA%20%E2%80%93%20INTEGRATING%20BUILDING%20INFORMATION%20MODELLING.pdf

Meterelliyoz, M. Ü., & Özener, O. Ö. (2017). Yapı Teknolojisi Eğitiminde YBM ve Pedagojik Potansiyeller (BIM in Building Technology Education and Pedagogical Potentials). *MSTAS 2017*, 239. http://mstas2017.metu.edu.tr/wp-content/uploads/2017/07/Bildiri-21.pdf

Morton, D. E. (2012). BIM: A transformative technology within the architectural curriculum in Schools of Architecture (Pedagogic Stages of Architectural Education and the Transformative Effect of BIM). *International Journal of 3-D Information Modeling (IJ3DIM)*, *1*(4), 50-68. https://pdfs.semanticscholar.org/cbc4/0b5bd864a092ef1830e08ed89ebd952deadf.pdf

Scheer, D. R. (2014). *The death of drawing: architecture in the age of simulation*. Routledge. https://www.routledge.com/The-Death-of-Drawing-Architecture-in-the-Age-of-Simulation/Scheer/p/book/9780415834964

Türkyılmaz, E. (2016). YBM'nin Mimarlık Eğitim Programı ile Bütünleşmesi Üzerine Bir Çalışma (An Example of BIM Integrated into Architectural Curriculum). *MEGARON/Yıldız Teknik Üniversitesi, Mimarlık Fakültesi E-Dergisi*, *11*(1), 78-88. https://www.journalagent.com/megaron/pdfs/MEGARON_11_1_78_88.pdf